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LUMINOSITY FUNCTIONS OF NORMAL GALAXIES IN PHOTORANGES AND RADIOBANDS

by

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SUMMARY

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The radioindices of nearest normal galaxies are considered. A dependence between the optical luminosity and radioindices of later-type galaxies is revealed. The luminosity functions of later and earlier-type galaxies were determined in the photographic range with the help of galaxy computations in the 1300 Mnc^3 volume in the vicinity of our Galaxy. Finally, the radioluminosity of normal galaxies was determined with the help of the photographic luminosity function and of radioindices of later-type galaxies.

AUTHOR

* * *

The extragalactic sources of weak radioluminosity are normal galaxies, whose number is great, and that is why their aggregate contribution to background radio emission is noticeable. Unfortunately, radioemission of normal galaxies is so weak that it could be reliably measured only near some close S and Im -galaxies, brighter than 9^m and, so far, was not detected at normal E- galaxies. Radioemission of more remote galaxies is very poorly detected and quantitative estimates of it are unreliable, which can be seen from the comparison of m_R estimates in the meter band [1 — 3]. The visible and absolute radioquantities in

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$\lambda = 1.9$ m (m_R and M_R) and radioindices $m_R - m^0_{pg}$ constitute convenient characteristics of normal galaxies' radio emission. Compiled in Table 1 are the integral photographic values of galaxies brighter than 9^m according to [4 – 12], the values of absorption according to [13], the radio-quantities according to [1 – 3, 14], the true models of distance according [15 – 17], determined by distance indicators, by their belonging to groups and red shifts at H = 100 km/sec in Mnc etc.. (the latter are brought out in parentheses). The mean radioindices of fundamental-type galaxies are compatible with the Brown estimates [18], but Sc- galaxies can be subdivided into two groups according to the radioindices.

TABLE 1

NGC (IC)	Type after [22]	m_{pg}	a_{pg}	m_R	$m_R - m^0_{pg}$	M_{pg}	Ref.
5194	*ScI*	$8^m,88$	$0^m,3$	$9^m,7$	$+1^m,1$	$(-20^m,1)$	[1]
6946	*ScI* (II)	9,67	1,2	9,5	+1,0	—19,8	[2]
253	*Sc(*)p*	8,1	0,4	9,0	+1,3	—19,8	[1,10]
5236	*Sc* I—II	8,4	0,5	8,8	+0,9	—19,6	[1]
5457	*Sc* I	8,20	0,3	9,4	+1,5	—19,5	[1,15]
4945	*SBc*	(8,8)	1,2	8,7	+1,1	—19,3	[1,16]
(342)	*Sc* I	8,7	1,7	7,8	+0,8	—19,2	[2,6]
598	*Sc* II—III	6,19	0,8	7,8	+2,4	—18,9	[2,15]
300	*Sc*	8,7	0,4	9,9	+1,4	—17,9	[1,7]
2403	*Sc* III	8,80	0,9	9	1,1	—18,8	[2,15]
55	*Im*	7,9	0,4	10,9	+3,7	—19,1	[1,8]
БМО	*I* III—IV	0,6	0,6	3,4	+3,4	—18,4	[1,9]
ММО	*I* IV	2,8	0,7	5,5	+3,4	—16,7	[1,9]
6822	*I* IV—V	9,21	0,7	10,7	+3	—15	[2]
(1613)	*I* V	10,00	0,4	7	+3	—14	[14]
224	*Sb* I—II	4,33	0,6	5,7	+2,0	—20,5	[2,15]
4258	*Sb (t:p)*	8,90	0,3	9,8	+1,2	(—19,9)	[1]
4736	*Sbp* II:	8,91	0,4	10,8	+2,3	(—19,2)	[1]
3031	*Sb* I—II	7,85	0,6	9,4	+2,2	—18,5	[2,15]
4594	*Sab*	9,18	0,5	11,3	2,6	—21,1	[1,15]
4526	*S0*	10,6	0,4	10,0	—0,2	—20,1	[3,15]
4472	*E0*	9,33	0,4	10,2	1,3	—21,5	[2,15]
221	*E2*	9,06	0,6	9,7	1,2	—15,7	[1,15]
205	*E 5p*	8,89	0,6	10,2	2,0	—15,9	[3,15]
185	*E 0p*	10,29	0,6	11	1,8	—14,8	[2,15]
For	*Ep*	(9,0)	0,4	10	3,7	—11,4	[1]
Sil	*Ep*	(9,0)	0,4	—	4,6	— 9,9	[1]
104	*Gc*	—	0,6	—	7,2	— 8,5	[1,17]
362	*Gc*	—	0,5	—	4,2	— 7,0	[1,17]

On the whole, however, S- and Im-galaxies indicate a specific course with the mean absolute photographic magnitude M_{pg} (Fig. 1), which is expressed by the following correlation formula :

$$m_R - m^0_{pg} = 18.7 + 0.9\, M_{pg} \qquad (1)$$

With the help of this dependence, one may determine the luminosity function of normal galaxies provided the photographic luminosity function is known. It all amounts to extrapolation of the results obtained by the close galaxies over a significantly greater volume, for which the photographic luminosity function of the galaxy is determined reliably.

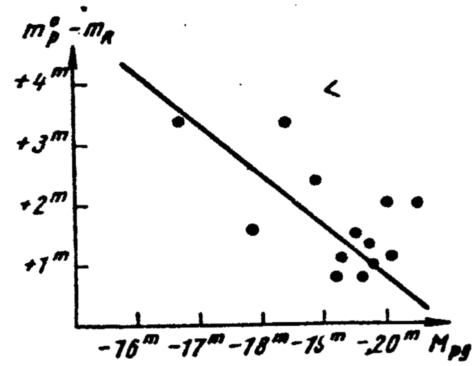

Fig. 1.- Dependence between the integral absolute photographic value of normal galaxies and the radio-index $m_R - m_{pg}^0$. The sign < denotes NGC 55, whose photographic magnitude is, visibly, somewhat weakened by absorption in this galaxy.

As to the radio emission of E- and SO- galaxies, there are two points of view [18].- Brown assumes that radio emission of systems with a stellar population of strictly type II (spherical) is not detected, because it generally is extremely weak. This is confirmed also by the negative results of search for radio emissions of globular clusters [1]. As to radio emission of nuclei of spiral galaxies, there is in these nuclei an admixture of type I population stars, neutral hydrogen and gas exchange with galaxy disk, i.e. there are reasons for radio emission. Roberts assumes that radio emission of elliptical galaxies already is at the threshold of detection by means of radiotelescopes. According to him, the single case of detection of radio emission from the SO-galaxy NGC 4526 [3], speaks in favor of it. But it is possible also that this is a casual coincidence of the radiosource and the galaxy or a doubtful identification (the difference by declination is 1^o). It is possible that Roberts is right in regard to SO- galaxies, in which traces of dust were revealed by him [19]. Nevertheless, radio emission from E- and SO- galaxies cannot now be considered as solidly established.

* * *

PHOTOGRAPHIC LUMINOSITY FUNCTIONS OF LATER AND EARLIER-TYPE GALAXIES

The luminosity function for galaxies of all types in the photographic scale of stellar magnitudes has been obtained by a series of authors [20 – 24] for the nearest environments of the Galaxy, but in this case the bright end of luminosity function was underestimated, inasmuch as the brightest galaxies are little represented in our environment. To the contrary, when the luminosity function was constructed by galactic star clusters, its weak end was underestimated. The same shortcoming is obtained at construction of luminosity function only by galaxies with well known red shifts. The joint consideration of the results of the first and second methods assumes an identical relative composition and luminosity of the galactic field and clusters, which is not correct in case of E-galaxies. That is why for the construction of luminosity function of normal galaxies we took advantage of the combination of the first and third methods. In this case the difficulty consists in that it is not clear whether or not the density of dwarf galaxies in our vicinity can be considered as typical for large volumes, in other words, whether the distribution of dwarf galaxies may be estimated as uniform. Fortunately, the radio emission of dwarf galaxies drops sharply with the decrease of their photographical integral magnitude and the share, contributed by them to the total radio emission is insignificant; that is why the nonuniformity on the distribution of dwarf galaxies will little affect the radioluminosity function.

In order to obtain the photographic luminosity function of galaxies, we choose a portion of the sky in 7.77 ster, which encompasses the northern and equatorial parts of the sky to $\delta = -25^{\circ}$, with the exception of the zone of avoidance with $|b| < 10^{\circ}$ and of the sky area the cluster in Virgo ($\alpha = 12 - 13^{h}$, $\delta = -10 - +20^{\circ}$). All the galaxies, brighter than 12^{m}, and corrected for the absorption according to [13] , which are situated in the spherical sector of radius 8 Mпс, were computed in the chosen portion. For the galaxies with red shifts of less than 300 km/s or for which data on distance indicators according to [14, 24] are available, estimates of distance were taken either by indicators or by appurtenance to galaxy groups. For the remaining galaxies the distances were taken by red-shifts with $H = 100$ km/sec p. Mnc. For a small number of galaxies, with no available data on red-shifts and indicators and not belonging to groups, the estimates by luminosity categories according to Van den Bergh were taken [25]. We included in our computations our own Galaxy and the Magellanic Clouds, that is all the members of the Local group except 1C 10. We included in the calculations the dwarf galaxies absent in the catalogue [11], but related to close groups according to [26]. The absorption was taken into account by the Parenago method with the help of the new absorption chart [13]. It should be recalled, that in [5] and other works, only the effect of latitude is taken into account while the absorption in the direction at the galactic pole is omitted. That is why the estimate of M_{pg} is there by 0.3^m brighter than in our own system, the distance scale remaining the same.

Galaxies to 12^m were borrowed from the catalogue of [11], with the integral magnitudes of galaxies taken according to [4, 5, 11] (they are enumerated in order of preference of estimates), the old estimates from [11] were reduced to the system of [4]. In our sector, with an 8 Mnc radius, the catalogue of [11] exhausts all the galaxies from -20 to 17.5^m; as to the galaxies weaker than -17.5^m, were computed in the same sector but in the volume of smaller radius R. Because of that, the computations of galaxies of different luminosity were referred to various volumes and the weak galaxies were computed in a rather small volume of space.

Presented in Table 2 are the results of computations of N galaxies of later (S + Im) and earlier (E + SO + SO) types with the indication of of spherical sectors' radii R, where computations were conducted; compiled also are the logarithms of the number of galaxies of given luminosity (M) per Mnc^3, that is the luminosity functions according to calculations and after smoothing out, and the integral luminosity function with its smoothed out variant.

These luminosity functions and their smoothed out variants are plotted in Fig. 2. Inasmuch as we conducted these computations in a comparatively small volume of space, we needed for the application of the obtained luminosity functions to larger volumes precisely the smoothed out functions, which are to some degree liberated from random fluctuations of calculations.

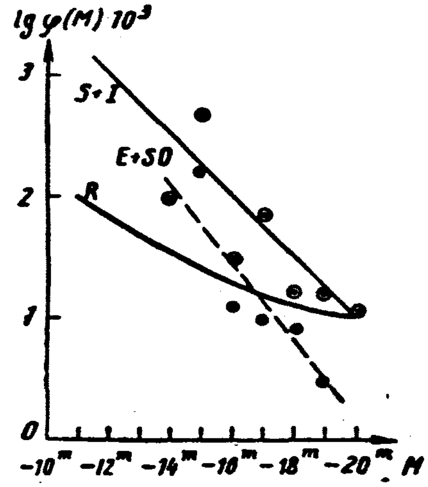

Fig. 2. - Optical and radio-luminosity functions of normal galaxies. S + Im are spiral and irregular galaxies, E + SO are earlier-type galaxies, R is radio-luminosity function of later-type galaxies.

Comparing the obtained luminosity functions with the relative one according to [22], we see an agreement for S-galaxies brighter than -16.5^m, but a significant discrepancy for weaker ones. This is expained by the difference in calculation methods more particularly sensitive for the calculation of weak galaxies, drawn out of a limit volume of space. Besides, clouds rich with type-Sb objects, say clusters in Virgo and Ursa Major, entered into the computations of reference [22].

The integral luminosity function of galaxies, brought out in the last column of Table 2, is generally consistent with the luminosity function determined by Zwicky [23].

TABLE 2

M_{pg}	R_1 Mpc	S + Im: N	S + Im: lg φ (M)·10³ calc	S + Im: lg φ (M)·10³ smoothed out	E + S0 + I0: N	E + S0 + I0: lg φ (M)·10³ calc	E + S0 + I0: lg φ (M)·10³ smoothed out	all types: lg φ (M)·10³ calc	all types: lg φ (M)·10³ smoothed out
-20^m	8	14	1,04	1,00	—	—	—	1,04	1,05
−19	8	21	1,21	1,15	4	0,49	0,5	1,29	1,25
−18	8	19	1,17	1,35	10	0,89	0,75	1,35	1,50
−17	5	22	1,83	1,60	3	0,97	1,00	1,89	1,70
−16	5	12	1,47	1,90	4	1,09	1,40	1,69	1,70
−15	2,5	18	2,65	2,20	6	2,17	1,75	2,77	2,40
−14	2,5	4	1,99	2,45	—	—	—	—	—
−13	1	4	3,19	2,75	—	—	—	—	—

RADIOLUMINOSITY FUNCTION OF NORMAL GALAXIES

It is not difficult to obtain the radioluminosity function of normal galaxies with the help of the dependence (1) and of the graph for the smoothed out function of photographic luminosity of late-type galaxies. It is brought out in Table 3. If the radio emission of earlier-type galaxies is still found to be significant, certain changes must be introduced in this function.

TABLE 3

M_R	$\lg \varphi(M) \cdot 10^3$
-20^m	1,00
−19	1,05
−18	1,10
−17	1,20
−16	1,30
−15	1,40
−14	1,55
−13	1,7
−12	1,9
−11	2,0

As to the typicalness of the radioluminosity function of normal galaxies for broader regions of Metagalaxy, the matter can be reduced to the typical and nontypical nature of the photographic luminosity function, provided we set aside the possible evolutional effects. The relative luminosity function of late-type galaxies in Virgo-type clusters and in the general metagalactic field is identical. As to the luminosity function of earlier-type galaxies, they are rather individual for the field and types of clusters. For example, supergiant E-galaxies are encountered in the Virgo cluster, while in Comae Berenices and other clusters the luminosity of E-galaxies is normal.

However, the typical function for substantial volumes of space is precisely the luminosity function, for clusters occupy in it a comparatively small part. For example, the Abell computations of the number of galaxy clusters per square degree to distances equivalent to red-shift 0.140 give 0.12 for cluster density per square degree [27], which is equivalent to a single cluster per $2 \cdot 10^6$ Mnc^3. Taking 40 Mnc for the mean diameter of clusters, called by Abell "cell radius", we obtain, that clusters occupy a volume of the order of 1 percent. The excess concentration of galaxies in a cluster over the field, by some hundred times relative to brightest objects, increases the photographic luminosity function for the average volume including the clusters, by a factor of 2.

Therefore, the radioluminosity function of normal galaxies, found by us, is typical for large volumes, if we discount the evolutional effects and the fractions contributed by elliptical galaxies and the intergalacting medium.

The mean absolute integral radioluminosity of 1 Mnc^3 is, according to Table 3, of the order of -16^m, because of radio emission of later-type galaxies and provided we take into account radio emissions of clusters and elliptical galaxies. Because of radio emission of radiogalaxies (assuming their $M_R \sim 30$, and starting from the idea that 200 radiosources to $m_R = 9.6^m$ are counted over a 0.6 area of the celestial sphere), the preliminary rough estimate of radioluminosity of a single Mnc^3 of space should be in all -11^m. Thus, the radio emission of normal galaxies contributes the main share to the observed radiobackground of Metagalaxy.

*** THE END ***

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REFERENCES

[N. B. The transliterations from Russian and the eventual title translations are given at the end.]

1. Mills B. Y. Handbuch d. Phys., 52, 237, 1959.
2. Brown R. H., Hazard C. Monthly Notices, 122, 479, 1961; 123, 279, 1961.
3. Leslie P. Observatory, 80, 216, 1960.
4. Holmberg E. Med. Lund Observatory Ser., II, No. 136, 1958.
5. Humason M. L., Mayall N. U., Sandage A. R. Astron. J., 61, 97, 1956.
6. Dieter M. H. Astron. J., 67, 313, 1962.
7. Vaucouleurs G. de Page J. Astrophys. J., 136, 107, 1962.
8. Vaucouleurs G. de. Astrophys. J., 133, 405, 1961.
9. Vaucouleurs G. de. Astrophys. J., 131, 574, 1960; 137, 363, 1963.
10. Whitford A. E. Astrophys. J., 83, 424, 1936.
11. Shapley H., Ames A. Harv. Ann., 88, No. 2, 1930.
12. Shapley H. Proc. Nat., Acad. of Sci. USA, 25, 565, 1939.
13. Шаров А. С. «Астрономический журнал», 40, 900, 1963.
14. Heeschen D. S. Publ. Nat. Radio Astron. Obs., 1, No. 9, 1961.

cont'd ../..

15. Sandage A. R. Problems of Extra-Galactic Research; I. A. U. Symposium No. 15, G. C. McVittie McMillan, N. Y., 1962, p. 359.
16. Vaucouleurs G. de. Problems of Extra-Galactic Research. N. Y., 1962, p. 3.
17. Sawyer-Hogg H. Handbuch d. Phys., 52, 1959.
18. Brown R. H. Problems of Extra-Galactic Research, ed. G. C. McVittie McMillan, N. Y., 1962, p. 79.
19. Roberts M. Astron. J., 65, 457, 1960.
20. Hubble E. Realm of the Nebulae, Yale Univ. Press, 1936.
21. Holmberg E. Medd. Lund Obs., Ser. II, No. 128, 1950.
22. Van den Bergh S. Zeitschrift f. Astrophys., 53, 219, 1961.
23. Zwicky F. Morphological Astronomy, Springer Verlg, 1957.
24. Псковский Ю. П. «Астрономический журнал», 38, 521, 656, 1033, 1961; 40, 385, 1963.
25. Van den Bergh S. Astrophys. J., 131, 215, 558, 1960.
26. Van den Bergh. S. Publs. Observ. Dunlap, 2, No. 6, 1960.
27. Abell G. O. Astrophys. J. Suppl., 3, No. 31, 1958.

* RUSSIAN TRANSLITERATION

[13].- A. SHAROV.- Astronomicheskiy Zhurnal, 40, 900 , 1963.

[24].- Yu. P. PSKOVSKIY.- Ibid. 38, 521, 656, 1033, 1961. 40, 385, 1963.

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